PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 4 :		(11) International Publication Number:
G05D 1/03, G01S 3/78, 5/16	A1	WO 89/03076
		(43) International Publication Date: 6 April 1989 (06.04.89)

(21) International Application Number: PCT/GB88/00768

(22) International Filing Date: 19 September 1988 (19.09.88)

(31) Priority Application Number: 8722403

(32) Priority Date: 23 September 1987 (23.09.87)

(33) Priority Country: GB

(71) Applicant *(for all designated States except US)*: THE SECRETARY OF STATE FOR TRADE AND INDUSTRY IN HER BRITANNIC MAJESTY'S GOVERNMENT OF THE UNITED KINGDOM OF GREAT BRITAIN AND NORTHERN IRELAND [GB/GB]; 10/18 Victoria, London SW1H 0ET (GB).

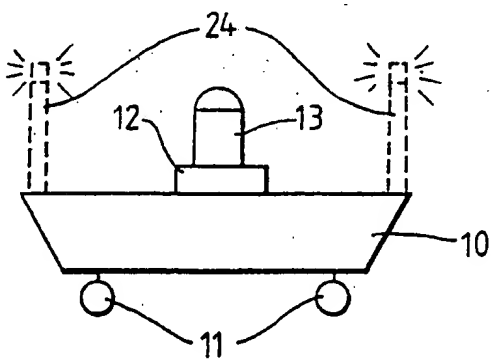
(72) Inventors; and
(75) Inventors/Applicants *(for US only)* : JACKSON, Douglas [GB/GB]; 46 Mount Cameron Drive, East Kilbride, Glasgow G74 2ES (GB). ROBERTSON, Andrew, Rae [GB/GB]; 7 Nenock Court, Hamilton, Nr. Glasgow (GB).

(74) Agent: BECKHAM, Robert, William; Ministry of Defence, Procurement Executive, Patents 1A(4), Room 2014, Empress State Building, Lillie Road, London SW6 1TR (GB).

(81) Designated States: AT (European patent), AU, BE (European patent), BR, CH (European patent), DE (European patent), DK, FR (European patent), GB, GB (European patent), IT (European patent), JP, KR, LU (European patent), NL (European patent), SE (European patent), US.

Published
With international search report.

(54) Title: AUTOMATIC VEHICLE GUIDANCE SYSTEMS



(57) Abstract

A bearing sensing device for use in an automatic vehicle guidance system has a lens, such as a fish eye lens (50) or a spherical reflecting lens (60), having a substantial angle of view in elevation and almost a full 360° view in azimuth. Light from the lens (50, 60) is focused onto a substantially annular photo detector (54), which is connected to means for relating a focusing point (72) on the photo detector (54) to a reference axis.

FOR THE PURPOSES OF INFORMATION ONLY

Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

AT	Austria	FR	France	ML	Mali
AU	Australia	GA	Gabon	MR	Mauritania
BB	Barbados	GB	United Kingdom	MW	Malawi
BE	Belgium	HU	Hungary	NL	Netherlands
BG	Bulgaria	IT	Italy	NO	Norway
BJ	Benin	JP	Japan	RO	Romania
BR	Brazil	KP	Democratic People's Republic of Korea	SD	Sudan
CF	Central African Republic			SE	Sweden
CG	Congo	KR	Republic of Korea	SN	Senegal
CH	Switzerland	LI	Liechtenstein	SU	Soviet Union
CM	Cameroon	LK	Sri Lanka	TD	Chad
DE	Germany, Federal Republic of	LU	Luxembourg	TG	Togo
DK	Denmark	MC	Monaco	US	United States of America
FI	Finland	MG	Madagascar		

AUTOMATIC VEHICLE GUIDANCE SYSTEMS

The present invention relates to devices for use in automatic vehicle guidance systems.

There are many known examples of automatic vehicle guidance systems involving the repeated movement of one or more vehicles. A simple example is the system used for the transfer of coal waste to slag heaps. More complicated systems are used in the movement of materials within factories and warehouses. However, these systems usually rely on rails or on fixed paths defined by, for example, buried guide wires, and are governed by inter alia, signals received from trip switches, photo-electric cells, or similar position sensors. The uses of such systems are therefore very inflexible, and are suitable only for the most routine type of task.

There is a requirement for more flexible systems, and one such system is described in Patent GB 2129161B. This Patent describes a flexible system whereby vehicles travel freely under the control of signals generated by computers in response to the detection by one or more fixed cameras of vehicle position, the vehicles being equipped with devices which transmit a frequency, such as an infra-red frequency, to which the camera or cameras respond.

With this type of system, if the cameras are situated at the same height as the transmitters on the vehicles, it is possible that certain vehicles will be masked from certain cameras at times. It is therefore advisable that the cameras be situated above the height of the vehicle transmitters. With this arrangement, however, the elevation of light entering the cameras is constantly varying, and may easily exceed the capabilities of a particular camera.

It may also, in some instance, be desirable to have cameras mounted on the vehicles and transmitters mounted at fixed positions. In this case, with normal cameras, the vehicles can only be used on very flat surfaces so that pitch and roll of a vehicle does not prevent reception of signals.

There is therefore a requirement for a device which can be used in an automatic vehicle guidance system which has the capability to cope with variations of reception angle.

According to the present invention a bearing sensing device for use in an automatic vehicle guidance system includes a lens having

almost a full 360° view in azimuth and a substantial angle of view in elevation, a focusing device for focusing a beam of light from the lens on to a substantially annular photo detector, and means for relating a focusing point on the photo detector to a reference axis.

The device is used, for example, in an automatic vehicle guidance system having a plurality of light emitting sources, henceforth referred to as beacons, and a plurality of bearing sensing devices. The beacons may be fixed, with the bearing sensing devices mounted on vehicles, in which case there will be a reference axis fixed relative to each vehicle; alternatively the bearing sensing devices can be fixed with the beacons mounted on vehicles, in which case the reference axis will be fixed relative to the bearing sensing devices. The beacons can advantageously be used in a sequentially pulsed fashion.

A preferred photo detector is formed from a continuous P-N junction together with a highly uniform resistive sheet. Suitable material is commercially available. Material is formed into an annulus with electrodes deposited at each end, forming a one-dimensional lateral effect photo-diode. When a point on the surface of this detector is exposed to light a photo-electric current is generated at the point. The current divides and flows through the resistive layer to the electrodes, which are normally tied to a ground potential.

The means for relating the focusing point to the reference axis preferably use a ratiometric converter which compares the ratio of currents flowing from the focusing point to each of the electrodes to define the position of the point on the annulus. The known fixed relationship of the detector relative to the axis then allows a relation to be made between focusing point and axis.

In one form of the device a "fish-eye" type of lens is used, positioned to give a field of view from approximately horizontal to almost vertical throughout almost a full 360° in azimuth, beams entering the fish eye lens being focused by a focusing lens onto the photo detector.

In another form of the invention a spherical reflecting lens is used, light reflected therefrom being focused onto the photo detector.

Some embodiments of the invention will now be described, by way of example only, with reference to the accompanying diagrammatic drawings, of which:

Figure 1 shows a vehicle of the type with which the device may be used.

Figure 2(a) and (b) show 2 environments in which the vehicle of Figure 1 can operate.

Figure 3 and Figure 4 are block diagrams of guidance systems for vehicles operating in the environments of Figure 2(a), Figure 2(b) respectively.

Figure 5(a) is detail of one embodiment of the invention.

Figure 5(b) is a section through a field of view of the device illustrated in Figure 5(a).

Figure 6(a) is a detail of a second embodiment of the invention.

Figure 6(b) is a section through a field of view of the device of Figure 6(a).

Figure 7(a) is a plan view of a photo detector as used in the invention, and

Figure 7(b) shows a potentiometric equivalent circuit for the photo dectector of Figure 7(a).

A vehicle with which a device according to the invention can be used (Figure 1) has a body 10 mounted on wheels 11 driven and steered according to commands from a control box 12. The vehicle 10 can operate in an environment (2)(a) in which a bearing sensing device according to the invention, 13, mounted on the vehicle receives signals from a plurality of fixed beacons 14; or in an environment (2(b)) in which beacons 24 (shown in ditted lines in Figure 1) mounted as far apart as possible on vehicle 10 send signals to fixed bearing sensing devices 23.

When operating in the environment illustrated in 2(a) the control unit 12 will typically contain (Figure 3) the bearing sensing device 13 which sends signals to a beacon check unit 30 and to a ratiometric converter 31. The beacon check unit 30 sends a signal to a timer controller 32 which passes signals to the ratiometric converter 31 and to a computer 33 which also receives a signal from the ratiometric converter 31. The computer then signals a pilot unit 34 which controls the steering and driving of the wheels 11. The fixed beacons 14 send sequentially pulsed signals according to the control of a flash timer 15.

When operating in the environment of Figure 2(b) the control unit 12 will typically contain (Figure 4) a radio receiver 40 which receives

signals from a transmitter 45 in a control unit 41 and which controls sequential flashing of beacons 24 and operation of a pilot unit 34. The ground control units contain a series of bearing sensing devices 23 each of which sends signals to an associated beacon check 30 and ratio metric converter 31. A signal from the beacon check 30 passes to a master timer 42 which sends signals to each ratiometric converter 31, to a master computer 43 and to a flash timer 44. The master computer 43 receives signals from each ratiometric converter 31 and sends command signals to a transmitter 45 which also receives signals from the flash timer 44, and which sends command signals to the receiver 40.

In one form of the present invention a bearing sensing device 13, 23, (Figure 5)(a) has an ultra-wide angle (fish eye) lens 50 directing a beam of light 51 from a beacon 14, 24 through a field stop 52 to a lens 53 which focuses the beam onto an annular photo detector 54. A bearing sensing device of this type has a field of view (Figure 5(b)) 55 extending from horizontal to within about 20° of the vertical.

In a second embodiment of the invention (Figure 6(a)) a beam of light 61 from a beacon 14, 24 passes through a cylindrical window 62 and is reflected by a spherical mirror 60 through a field stop 52 to be focused by a lens 53 onto an annular photo detector 54. The cylindrical window 62 must be robust as well as of good optical quality as it must support the field stop 52, lens 53, and photo detector 54 and associated structure (not shown in this figure) which must be situated above the spherical mirror 60. The field of view of this type of bearing sensing device (Figure 6(b)) extends from slightly below the horizontal to slightly less than vertical.

The annular photo detector 54 (Figure 7(a)) is in the form of an annulus extending over almost 360° and is formed from a continous P-N junction together with a highly uniform resistance sheet. Electrodes 70, 71 are deposited on the ends of the annulus. In use, when a beam of light falls on a point 72 of the annulus 54 current passes to both electrodes 70 and 71, and by comparing these currents, in a manner analogous to that illustrated in 7(b), the position 72 along the annulus can be identified.

When one or more bearing sensing devices according to the invention are used on vehicles operating in an environment such as that illustrated in Figure 2(a) the beacons 14 sequentially emit flashes of

light under the control of the flash timer 15. Considering just one flash of light from one beacon and one vehicle 10 the bearing sensing device 13 on the vehicle 10 senses the flash of light and signals the beacon check 30 which checks (in a manner which forms no part of the current invention) which beacon sent the signal, and passes this information to the timer 32. A signal corresponding to the currents passing along the paths 72-70 and 71-70 is also passed to the radiometric converter 31 which calculates the position of the point 72 on the annulus 53 and compares this with the known position of an axis 16 of the vehicle 10 to give the bearing of the beacon 14 which is identified from the timer 32. This information is fed to the computer 33 and stored. When 2, or more usually more than 2, beacon bearings are being stored by the computer it calculates the position of the vehicle 10 and signals the pilot unit 34 to make any necessary adjustments to the steering and speed of the vehicle 10. It will be realised that light must not be allowed to fall on the electrodes 70, 71 of the photo detector 53, hence there is a blind spot of, typically, 3° in the bearing sensing device 13 and hence there will usually need to be more than 2 beacons 14 taken into consideration when calculating the position of the vehicle 10.

When bearing sensing devices 13 are used in the environment of Figure 2(b), considering one vehicle 10 only, a signal from transmitter 15 is received by receiver 40 which relays the information of flash timer 44 to sequentially operate beacons 24. Signals from the beacons 24 are picked up by the array of bearing sensing devices 23, and information from these is sent, by a manner similar to that described above with reference to the environment of Figure 2(a), to the computer 43 which works out the bearing of each beacon 24. The computer 43 selects the most suitable beacon bearings and thus computes the position and alignment (as the vehicle 10 has two beacons 24), of the vehicle 10 relative to a convenient set of co-ordinates.

It will be realised that operating in each of the environments 2(a), (b) will have its own advantages and disadvantages. For example in environment 2(a) the blind spot due to the electrodes 70, 71 on the photo detector 53 may be a disadvantage, but this environment does not require the use of a radio transmitter such as required in environment 2(b). As each vehicle 10 has its own computer 33 this can be compara-

tively simple, compared with the Computer 43 of environment 2(b). On the other hand the arrangement of environment 2(b) enables the computer 43 to store the positions and vector velocities of all vehicles 10 and arrange for collisions to be avoided.

Also each of the devices described above with reference to Figures 5, 6 has its own advantages. The lens 50 might be expected to be more accurate than the spherical lens 60, but does tend to be much more expensive.

It will be realised that whilst the bearing sensing devices have been described above as operating in 2 particular environments they may be equally valuable in other operating regimes.

Claims

What is claimed is:

1. A bearing sensing device (13) for use in an automatic vehicle guidance system characterised in including a lens (50, 60) having almost a full 360° view in azimuth and a substantial angle of view in elevation, a focusing device (53) for focusing a beam of light from the lens on to a substantially annular photo detector (54) and means for relating a focusing point (72) on the photo detector (54) to a reference axis.

2. A bearing sensing device (13) as claimed in Claim 1 characterised in that the lens (50) is of the "fish-eye" type.

3. A bearing sensing device (13) as claimed in Claim 2 characterised in that the lens (50) is positioned to give a field of view in elevation from approximately horizontal to almost vertical.

4. A bearing sensing device (13) as claimed in Claim 1 characterised in that the lens (60) is a spherical reflecting lens.

5. A bearing sensing device as claimed in Claim 4 characterised in having a field of view in elevation from slightly below horizontal to slightly less than vertical.

6. A vehicle guidance system having a plurality of bearing sensing devices (13) as claimed in any one of Claims 1 to 5.

7. A vehicle guidance system as claimed in Claim 6 where the bearing sensing devices are at fixed positions.

8. A vehicle guidance system as claimed in Claim 6 wherein the bearing sensing devices (13) are mounted on vehicles (10).

Fig. 1.

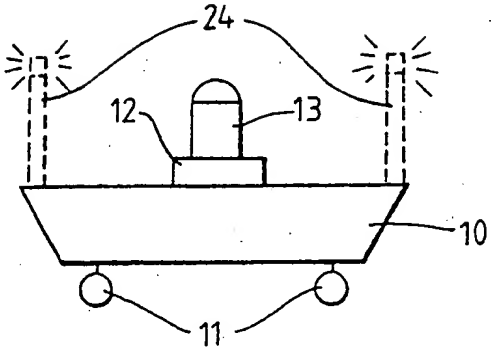
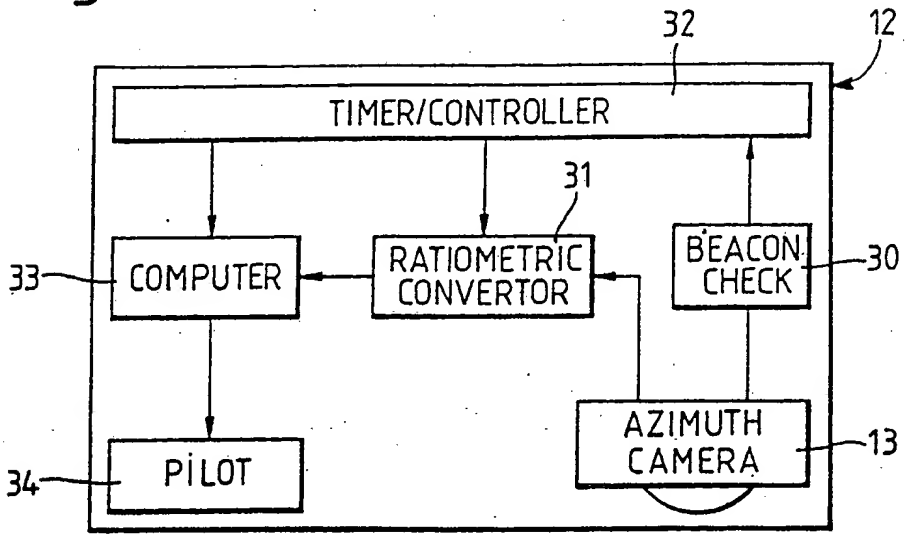

24
12
13
10
11

Fig. 3.


32
12
TIMER/CONTROLLER
31
33
COMPUTER
RATIOMETRIC CONVERTOR
BEACON CHECK
30
AZIMUTH CAMERA
13
34
PILOT

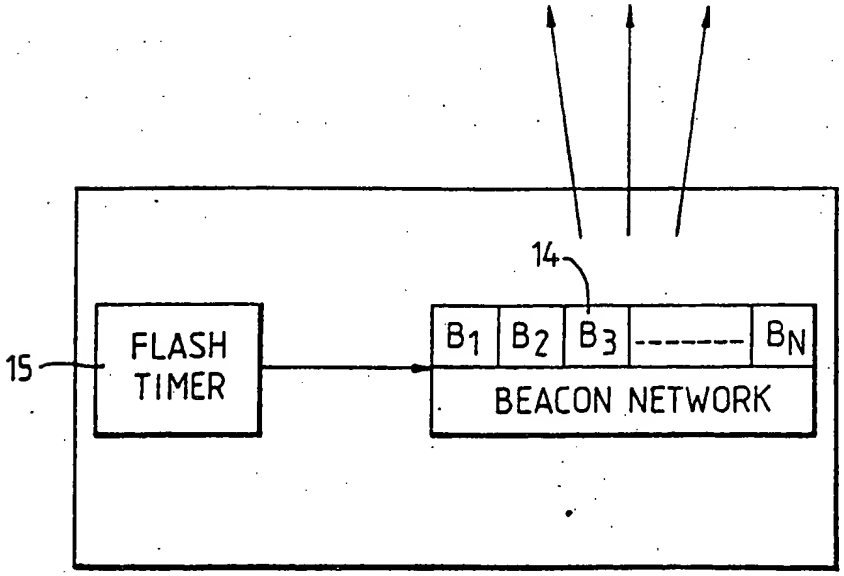

14
15
FLASH TIMER
B1
B2
B3
BN
BEACON NETWORK

Fig.2b.

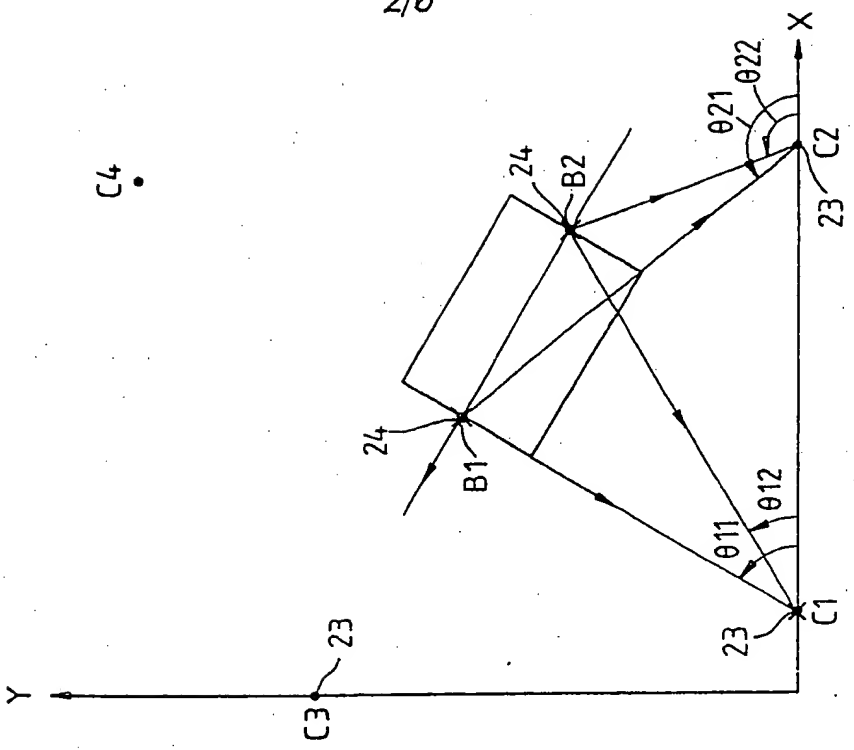

X
Y
C4
C3
C2
C1
B1
B2
23
24
θ21
θ22
θ11
θ12

Fig.2a.

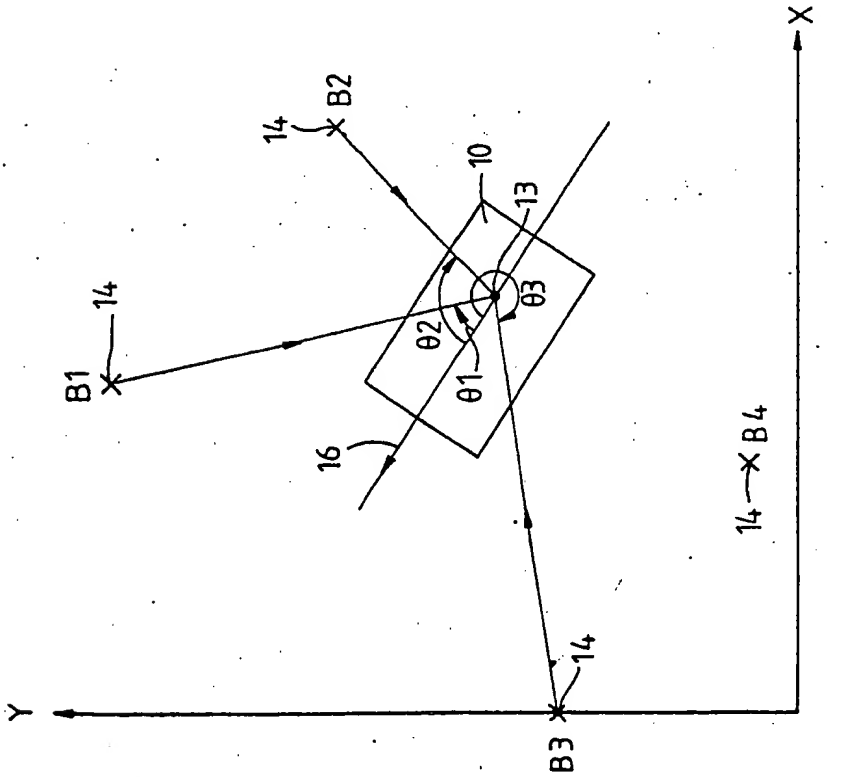

X
Y
B1
B2
B3
B4
14
10
13
16
θ1
θ2
θ3

Fig.4.

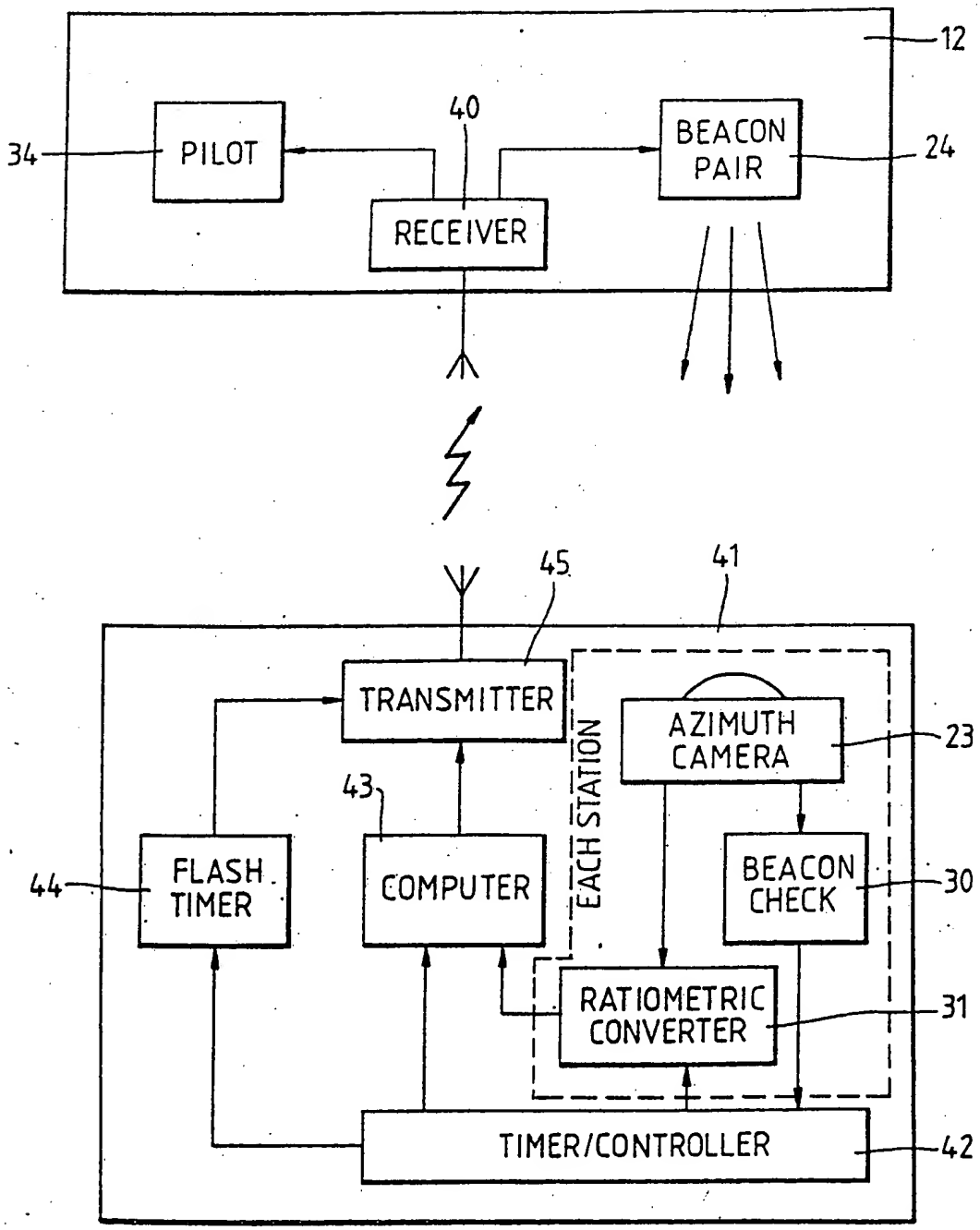

12
34
PILOT
40
RECEIVER
BEACON PAIR
24
45
41
TRANSMITTER
EACH STATION
AZIMUTH CAMERA
23
43
44
FLASH TIMER
COMPUTER
BEACON CHECK
30
RATIOMETRIC CONVERTER
31
TIMER/CONTROLLER
42

Fig.5a.

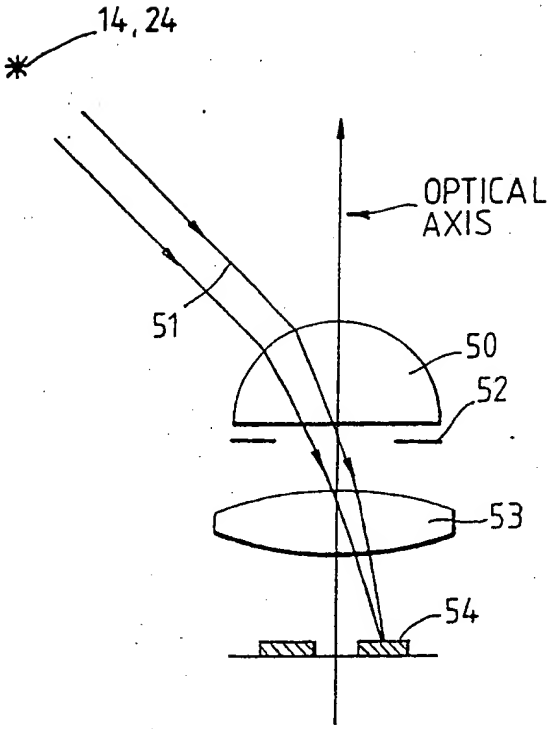

14, 24
OPTICAL AXIS
51
50
52
53
54

Fig.6a.

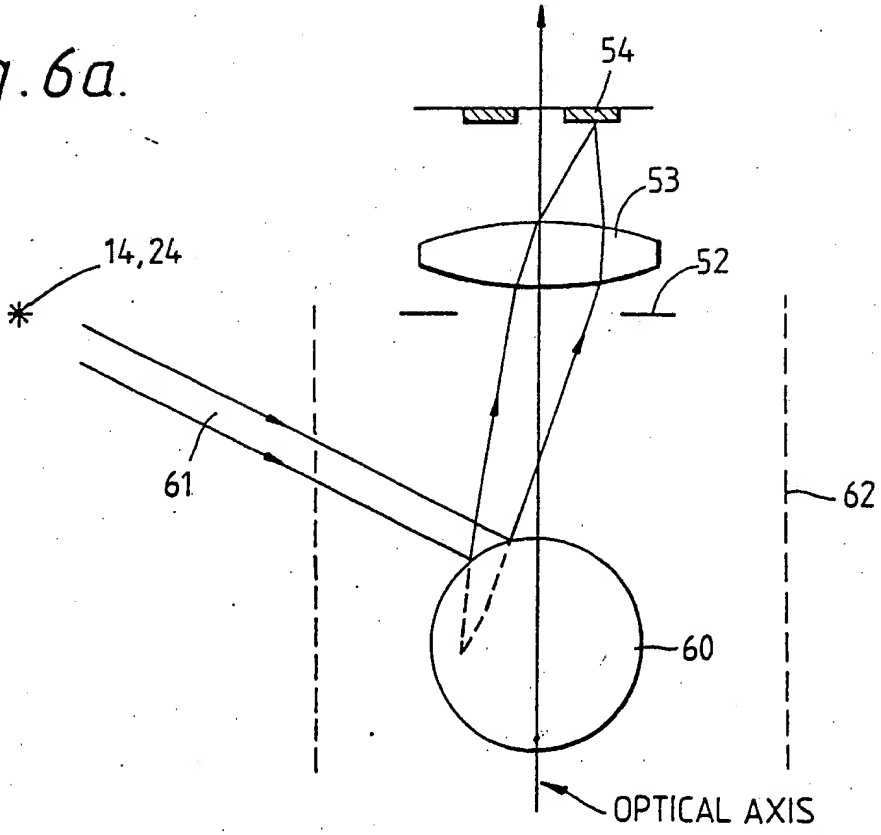

54
53
14, 24
52
61
62
60
OPTICAL AXIS

Fig.5b.

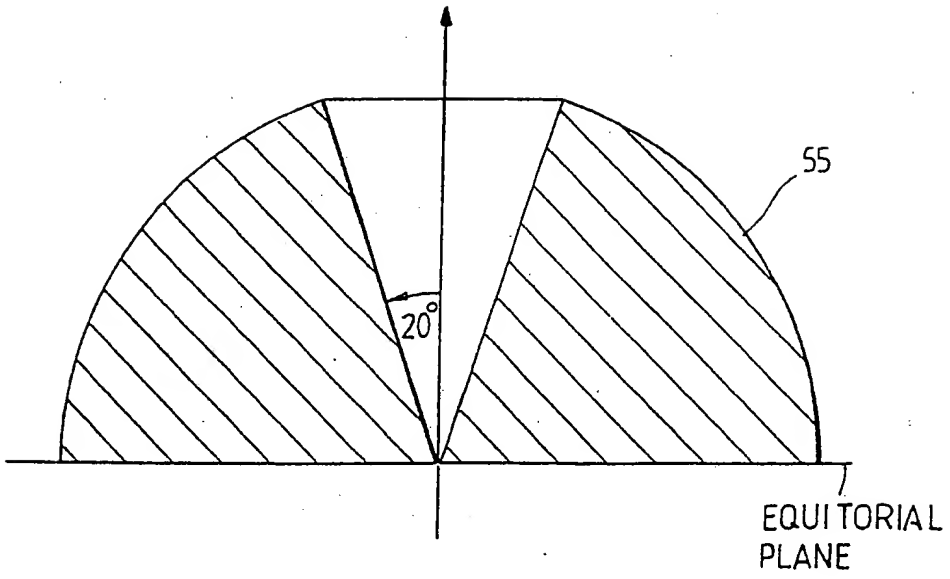


Fig.6b.

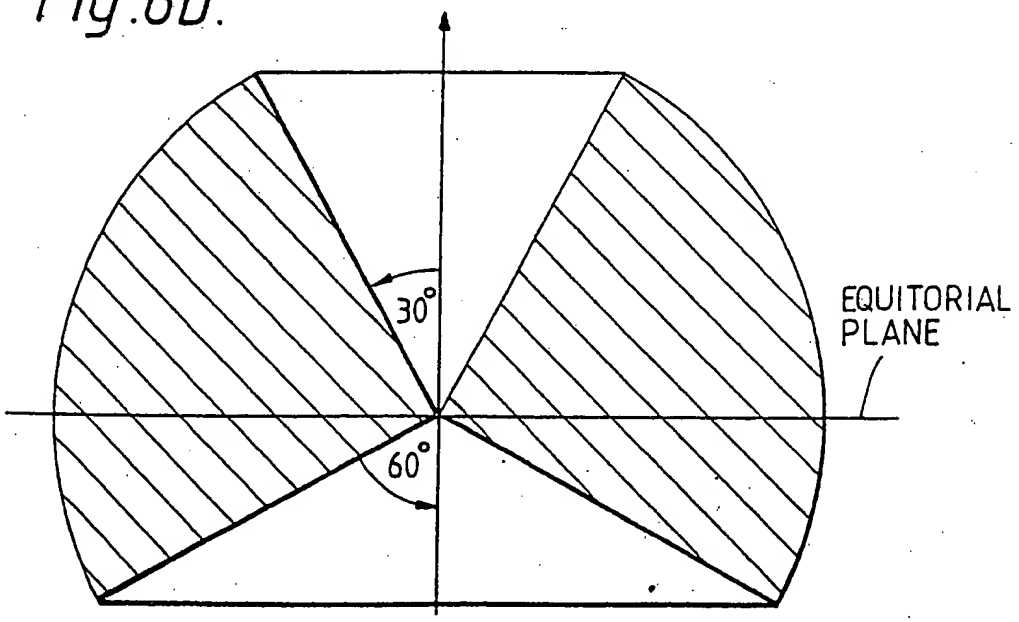


Fig.7a.

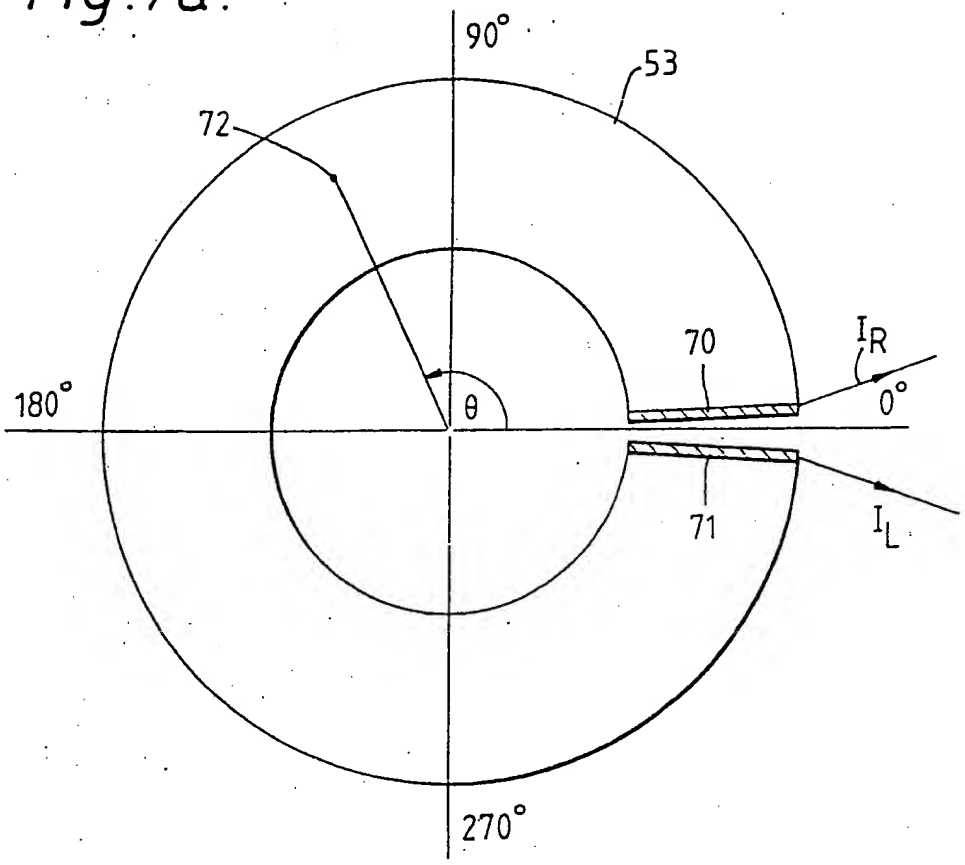
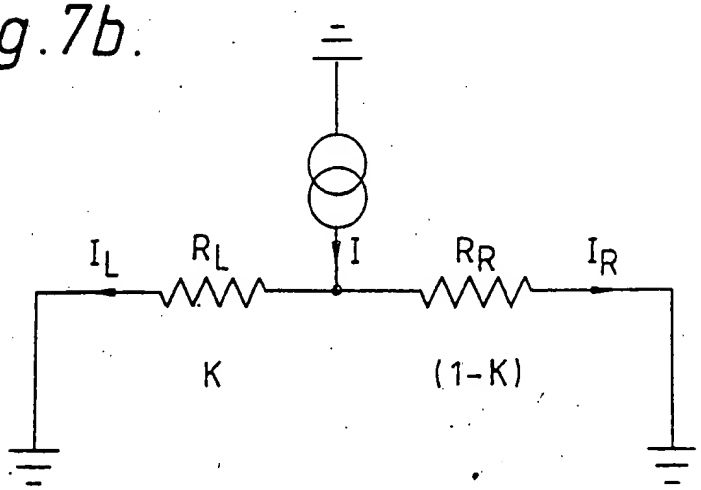


Fig.7b.



INTERNATIONAL SEARCH REPORT

International Application No PCT/GB 88/00768

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC[4]: G 05 D 1/03; G 01 S 3/78; G 01 S 5/16

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC[4]	G 05 D; G 01 S

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category [10]	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	GB, A, 2129161 (O.B. WILDMAN, PROCUREMENT EXECUTIVE, MINISTRY OF DEFENCE) 10 May 1984, see page 1, line 111 - page 2, line 15; figures (cited in the application)	1-8
Y	EP, A, 0198792 (THE UNIVERSITY OF CINCINNATI) 22 October 1986, see page 5, line 19 - page 13, line 34; figures 1-3	1-4
Y	EP, A, 0221643 (TEXAS INSTRUMENTS INC.) 13 May 1987, see page 5, line 18 - page 8, line 7; page 13, line 9 - page 18, line 20, figures 1,9,10,11,13	5-8

* Special categories of cited documents: [10]

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
16th December 1988	13. 01. 89
International Searching Authority	**Signature of Authorized Officer**
EUROPEAN PATENT OFFICE	P.C.G. VAN DER PUTTEN

ANNEX TO THE INTERNATIONAL SEARCH REPORT ON INTERNATIONAL PATENT APPLICATION NO. GB 8800768 SA 24343

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 05/01/89
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
GB-A- 2129161	10-05-84	None	
EP-A- 0198792	22-10-86	JP-A- 61275912	06-12-86
		US-A- 4670648	02-06-87
EP-A- 0221643	13-05-87	US-A- 4789940	06-12-88
		US-A- 4779203	18-10-88
		US-A- 4706120	10-11-87
		JP-A- 62229306	08-10-87
		US-A- 4750123	07-06-88